Numerical Weather Prediction

An improved visibilty scheme for Nimrod

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An Improved Visibility Scheme for Nimrod

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1 Abstract

The Marshall-Palmer drop size distribution for rainfall, and an exponential size distribution for snow with the Cox/Golding constants for snow at 0°C are used to produce an extinction coefficient for precipitation (of rain, snow or mixed rain and snow). This enables the Nimrod visibility program to include the effects of precipitation in the analyses and forecasts by using the Nimrod rain rate analyses and forecasts.
The paper demonstrates the improvements gained from this technique using both statistical and case study data. The technique will be used operationally from July 2002.

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2 Introduction

Prediction of poor visibility is a key requirement for all forms of transport *Golding* (1998).

The existing Nimrod Visibility Analysis / Forecast System (VAFS) in Nimrod, the Met Office very-short-range forecasting system, was developed in 1996 (*Golding*, 1995, 1998 and *Wright*, 1997) and calculates the Visibility, Worst Visibility, and three Fog Probability fields (200m, 1km & 5km) using mesoscale model aerosol concentration alongside current and recent SHIP and SYNOP reports for the analysis and hourly forecasts with a maximum lead time of 6 hours. This predicts poor visibility events such as radiation fog and hill fog.

The resultant forecasts from this scheme have the limitation of not taking into account precipitation, sometimes a major factor in reducing the visibility to a potentially dangerous level especially in cases of snow. (See Figure 2.1)

The Unified Model already has an adjustment scheme in place *Clark et al.* (2001). The new Nimrod scheme is based on the Unified Model scheme to keep the continuity between the two models.

This report describes the adjustments made to the existing scheme and the results of testing the scheme in the current Nimrod environment.

For an overview of the adjustments made in this project, see section 8.

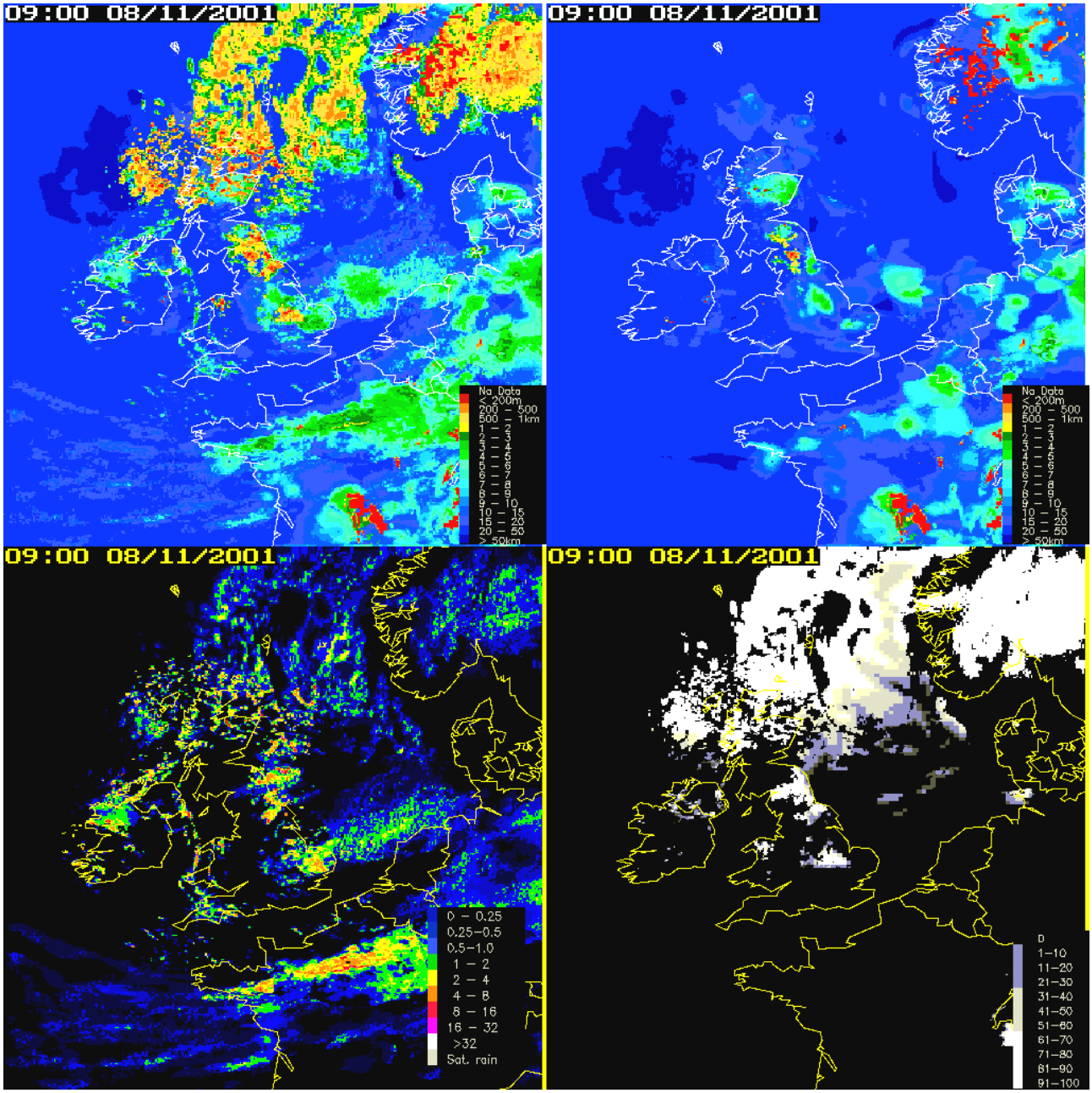

Figure 2.1: The dramatic effect of snow showers on visibility in the new scheme. Top Left: Output from new scheme. Top Right: Output from operational scheme. Bottom Left: Merged rain rate analysis. Bottom Right: Snow probability

3 Theory

3.1 Precipitation Adjustment

No attempt is made to account for the effect of precipitation during the existing visibility analysis.

A new subroutine has been produced which calculates the expected visibility through any precipitation present, and applies this to the output from the visibility analysis. Hence from *Wright (1997)* & *Clark (1998)*:

$$Visibility = -\frac{\ln \in}{\beta_{tot}} \quad (1)$$

$$\beta_{tot} = \beta_{air} + \beta_{aerosol}(RH) + \beta_{precip} \quad (2)$$

Where $\beta_{aerosol}$ is calculated as before *Clark* (1998) *and Wright* (1997):

$$\beta_{aerosol}(RH) = \int \pi Q(r) r^2 (RH, r_d) n(r_d) dr_d \quad (3)$$

The WMO recommended value for $ln \in$ is –3.0. However, Nimrod uses –3.9 as used in the Unified Model by *Clark* and first calculated by *Koschmeider* (1924).

For consistency with the mesoscale model, the same assumed hydrometeor size distribution is used as found in *Clark* (2001); a Marshall-Palmer drop size distribution for rain and an exponential size distribution for snow with the Cox/Golding constants for snow at 0°C.

This allows us to use a power law visibility-precipitation relationship of the form:

$$\frac{1}{Visibility} = \beta_{precip} = Factor \times Rainrate^{power} \quad (4)$$

where *power* and *factor* are predetermined for rain and snow by the particle size distribution, and *Rainrate* is in m/s.

Snowfall is determined from the snow probability output from the Nimrod precipitation analysis scheme. See Section 3.2 for detail on when snow is assumed.

The values of factor and power are determined from *Clark 2001*, as shown in Table 3.1 and Figure 3.1.

	Rain	Snow
Factor	5.2935	2105.0
Power	0.6429	0.8506

Table 3.1: Values of Factor and Power for Precipitation Types.

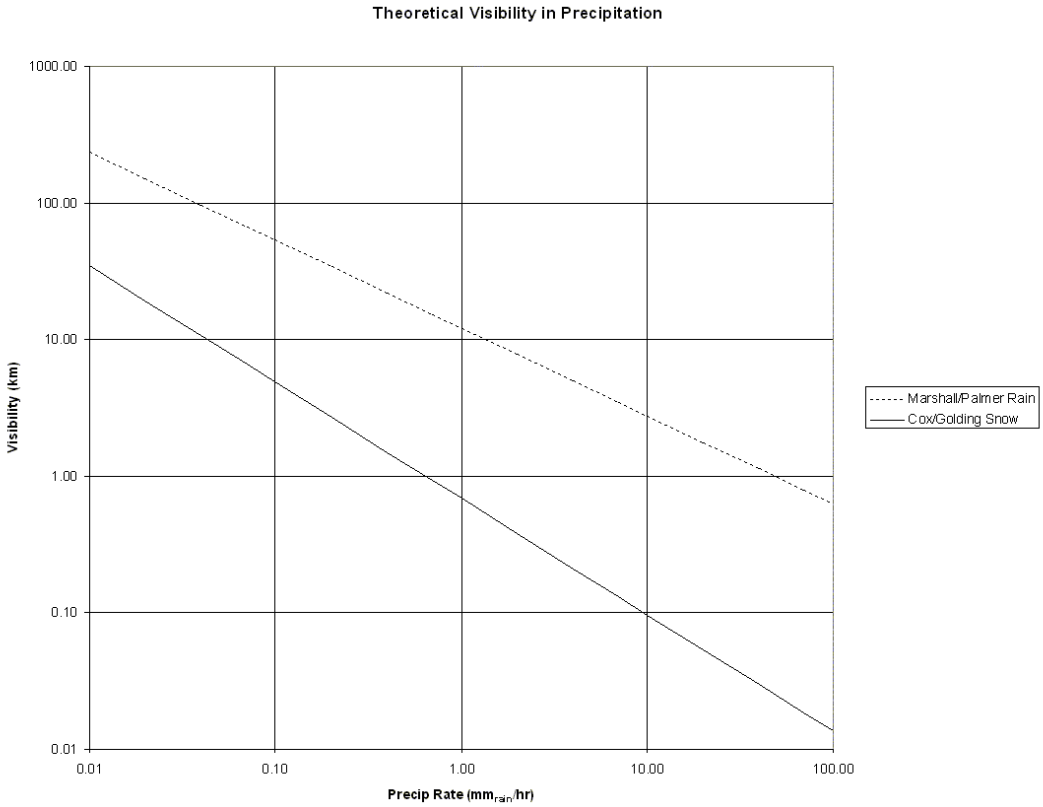

Figure 3.1: Plots of Visibility against Precipitation Rate in Rain and Snow

3.2 Mixed Rain and Snow

Some pixels will fall below the snow probability threshold, and yet still contain some snow crystals. To overcome this, and to prevent a jump from the rain to the snow algorithms, a sliding scale has been used for all the pixels which fall between the threshold snow probability for 'all snow', P_{snow}(snow thresh), and the threshold snow probability for 'no snow', P_{snow}(rain thresh).

The values used to determine these threshold probabilities are the same as those used for determining the precipitation type in the Nimrod precipitation forecast.

$$P_{snow}(\text{snow thresh}) = 0.6 \quad (5)$$

$$P_{snow}(\text{rain thresh}) = 0.1 \quad (6)$$

This gives four possible results.

$RR=0.0$ mm hr^{-1}

$RR>0.0$ mm hr^{-1} & $P_{snow} > P_{snow}$(snow thresh)

$RR>0.0$ mm hr^{-1} & P_{snow}(rain thresh) $< P_{snow} <$ P_{snow}(snow thresh)

$RR>0.0$ mm hr^{-1} & $P_{snow} <$ P_{snow}(rain thresh)

The first is simple. The program does not change the visibility at this point, as there is no precipitation.

The second and fourth possibilities require the use of Equation (4) and the appropriate values from Table 3.1 for either rain or snow.

The third possibility is for mixed rain and snow. Here the program calculates Equation (4) twice, once with the values for rain (giving β_{rain}), and once for snow (giving β_{snow}). The value of P_{snow} for this pixel is then used to determine where on the sliding scale (*ratio*) the pixel is:

$$ratio = \frac{P_{snow} - P_{snow}(rain.thresh)}{P_{snow}(snow.thresh) - P_{snow}(rain.thresh)} \quad (7)$$

$$\beta_{precip} = ratio \times \beta_{snow} + (1 - ratio) \times \beta_{rain} \quad (8)$$

3.3 Fog Probability

The current 200m, 1km and 5km fog probability fields are calculated using a triangular distribution of probability around a median total water content for the pixel, qt_{med}. A value for the threshold total water content qt_{thresh} is calculated from a Vis_{thresh} value equal to the field threshold value (i.e. 200m, 1km or 5km) *Wright* (1997) *and Clark* (1998). To take into account precipitation, this Vis_{thresh} value has been altered using the results of the visibility fields described above. The value for the visibility due entirely to the precipitation, $Vis_{precip}\left(=\frac{\ln \in}{\beta_{precip}}\right)$, is recalculated from the two visibility fields ($Vis_{before\ precip\ adjust}$ & $Vis_{after\ precip\ adjust}$):

$$\frac{1}{Vis_{precip}} = \frac{1}{Vis_{after.precip.adjust}} - \frac{1}{Vis_{before.precip.adjust}} \quad (9)$$

If there is no rainfall at a pixel, the value for Vis_{precip} is set as 0. Infinity would be the mathematically correct value to use, but 0 is easier to use in a computer program.

This value is then applied to the existing Vis_{thresh} value to create a new, higher threshold visibility value, $Vis_{precip.thresh}$, from which to calculate qt_{thresh} and thus the fog probability as the program already operates.

$$\frac{1}{Vis_{precip.thresh}} = \frac{1}{Vis_{thresh}} - \frac{1}{Vis_{precip}} \quad (10)$$

For zero values, where there is no precipitation, the program processes the data as it did before these changes came into effect, using Vis_{thresh} to calculate qt_{thresh}. The values of qt_{med} and b_s are also used to calculate the probability of a visibility less than Vis_{thresh} occurring *Wright* (1997), as shown in Figure 3.2. The probability is given by the fractional area of the triangle which is shaded.

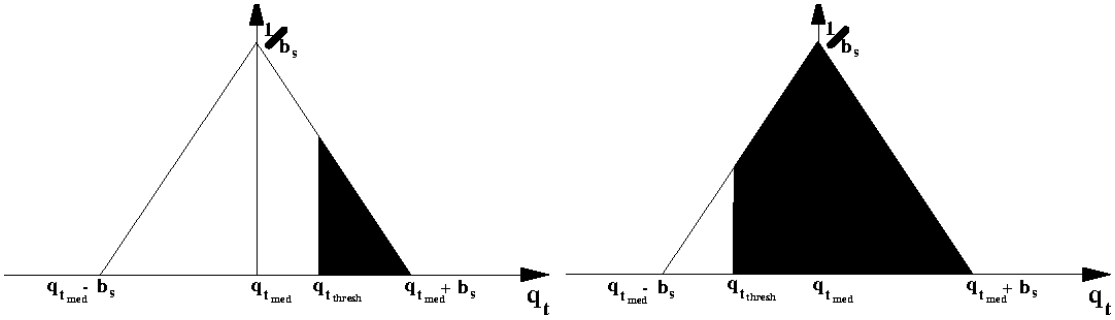

Figure 3.2: Schematic of assumed sub-grid distribution of total water, showing proportion of distribution greater that a threshold; on the left the threshold is greater than the median, on the right, less than. Wright (1997)

3.4 Removal of Selected Observations

The initial results from the trial suggested that in the regions of observing stations, analysed visibilities were lower than expected. The difference means that visibilities typical of heavy rainfall are being diagnosed in regions of light rainfall. This was believed to be caused by double accounting for the effect of precipitation on visibility.

3.4.1 Double Accounting

Double accounting occurs when an observation is taken in precipitating conditions. This is because the reported visibility takes into account the precipitation. This is then ingested by the visibility analysis program as an enhancement of aerosol concentration in the atmosphere and the visibility field is decreased to account for the observation.

When the program includes the effect of the precipitation, it merges the visibility coefficient for the precipitation with the visibility coefficient for the analysed visibility field which already includes the observations. Thus for the region close to the observation point, the effect of rainfall on visibility has been accounted for twice.

To compensate for this, a new version of the program was developed which eliminates any observations in the precipitation regions where the radar rain rate field is greater than 0.25 mm hr^{-1} after the observations have been quality controlled. Rain rates of less than 0.25 mm hr^{-1} have a negligible effect on visibility analysis in comparison to the effect of the observation. This change was only tested in the Case Studies detailed in sections 5 & 0 and has not been made operational.

It may be advantageous to use the air temperature and dew point temperature of these observations, removing only the visibility field, but this was not tested.

4 Verification

To numerically compare the results of the new scheme, without the selective removal of observations in precipitation, with the results from the operational scheme, the same verification program as is used operationally was applied (*Wright* (1997)).

A more detailed approach was used in the case studies. By studying the pattern of forecast against observed visibilities, a detailed comparison was made between the results of the operational scheme, and the new scheme, both with and without the selective removal of observations in precipitation. The method used is detailed in section 5.3.

4.1 Verification of Forecasts against Nimrod analyses

Before verifying against analyses, both the forecast and analysis fields are smoothed using a recursive Gaussian filter with a 25km half-width at half height thresholded at 200m and 1km. From this, the contingency table elements (used to calculate the monthly skill scores see below) are calculated.

4.2 Verification of Forecasts against Observations

Forecast verification against Observation (land station), for the above thresholds, also generates two sets of skill scores. One set is derived from an area-based scheme whereby the land is split into 13 geographical regions and the contingency table elements are generated for each area.

4.3 Definitions of the Statistics

General statistics such as the mean factor (meanF), root mean square factor (RMSF), percentage of visibility forecasts that are within 30% or 200m of the observed visibility (P30) and the percentage of temperature and dew point forecasts that are within 2 degrees of the observed values (P2) are generated by direct comparison of the forecasts with observation/analysis fields.

Root mean square factor and mean factor are given by:

$$RMSF = e^{\left\{\frac{1}{N}\sum_{i=1}^{N}\ln\left(\frac{F_i}{G_i}\right)^2\right\}^{\frac{1}{2}}} \qquad (11)$$

$$MeanF = e^{\left\{\frac{1}{N}\sum_{i=1}^{N}\ln\left(\frac{F_i}{G_i}\right)\right\}} \qquad (12)$$

where N is the number of valid samples, F_i is the forecast value and G_i is the analysed value. These statistics are derived using all values of visibility.

In addition, the operational verification software produces statistics for 200m and 1km thresholds. These thresholds are too low for rain to have an impact in testing the new visibility scheme, although an impact is found when snow occurs. However output from the verification software of Fog

Probability allowed the 5km threshold to be used to produce similar statistics to those achieved with the lower thresholds. (See Section 4.4)

The Statistics produced from these thresholds are as follows:

For a given event, E, if A is the frequency of E observed/analysed and forecast (a hit), B is the frequency of E observed/analysed and not E forecast (a miss) and C is the frequency of not E observed/analysed and E forecast (a false alarm), Hit Rate (*HR*), False Alarm Rate (*FAR*) and Critical Success Index (*CSI*) are:

$$HR = \frac{A}{A+B}$$
$$FAR = \frac{C}{A+C} \qquad (13)$$
$$CSI = \frac{A}{A+B+C}$$

4.4 Fog Probability

The 5 km fog probability was only evaluated against observations, as this is all that is available from the operational verification software.

The statistics for the 5km Fog probability are produced using a slightly different method. For each case, the observed visibility falls above or below the 5km threshold. The Fog probability can fall into one of 13 percentile categories:

0 0-5 5-15 15-25 25-35 35-45 45-55 55-65 65-75 75-85 85-95 95-100 100

Thus by summing the data in these 26 different categories, we can form a hit rate, false alarm rate and critical success index. The threshold used to do this calculation was 65%. Thus any forecast of fog probability over 65% where the visibility was actually greater than 5km is declared a false alarm, if instead the visibility is less than 5km, this forecast is declared a hit. A miss is defined as a forecast of less than 65% probability for an observed visibility of less than 5km. (See Figure 4.1)

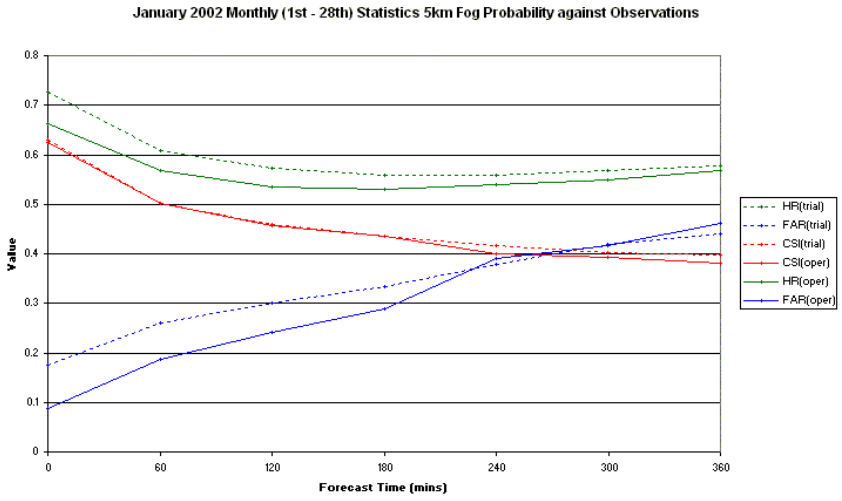

Figure 4.1: Statistics from a comparison between the old and new Scheme for Forecast

against observation of visibilities less than 5km

4.5 Results

4.5.1 Subjective Evaluation

The qualitative results of this scheme are very plausible compared to the operational scheme when precipitation is present. Figure 2.1 shows how the effect of precipitation, especially snow, can have a huge impact on the background visibility field.

In conversation with one of the members of the Aviation Forecasting bench in the National Meteorological Centre, on a day of Warm Front rain preceded by snow, the new trial scheme was praised as being 'one-up on the Mesoscale Model' with the higher resolution available and the higher frequency of forecast update times. The trial's forecast visibilities were described as 'much more realistic' than the previous operational model. The Nimrod output would now be considered in visibility forecasting.

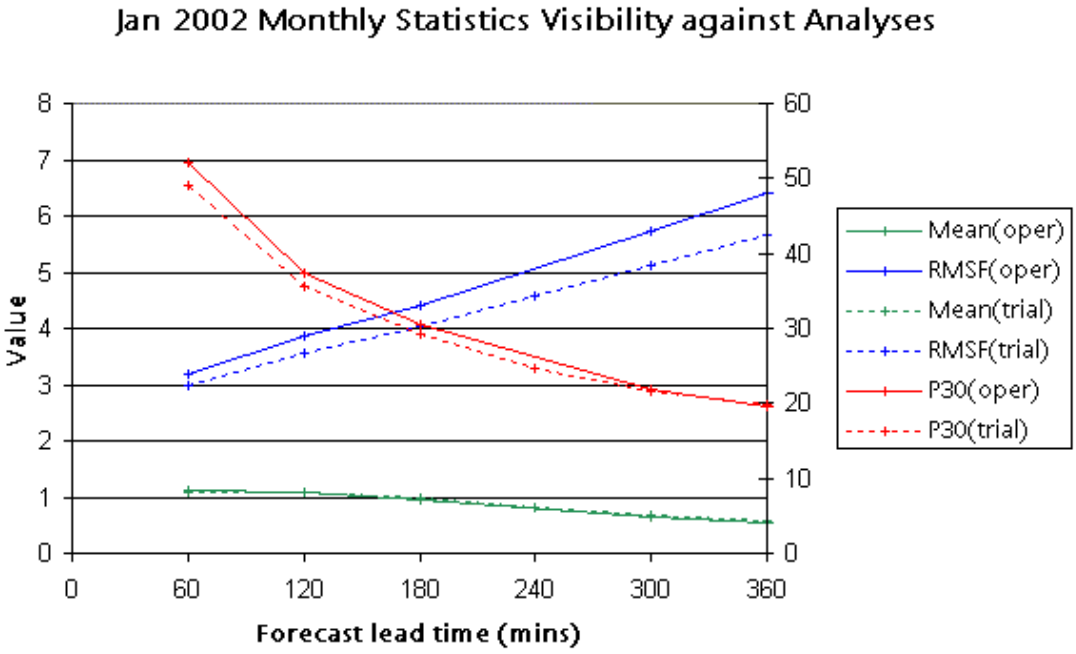

Figure 4.2: Statistics for January 2002 showing a comparison between the old and New schemes for forecasts evaluated against subsequent analyses of visibility for the entire range of visibility The scale for P30 is shown on the right hand axis.

4.5.2 Quantitative Evaluation

For a definition of the statistics discussed here, see section 4.3.

Figure 4.2 contains plots of the visibility statistics for forecasts compared with the subsequent analyses for both the operational (oper) scheme and the new (trial) scheme. These show the new scheme producing a decrease in the RMSF value (an improvement) while the mean remains the same, and the P30 value becomes slightly worse.

Figure 4.3 contains a similar plot of the visibility statistics and temperature statistics for the forecasts compared with the synoptic observations for

both the operational and the new schemes. These show the new scheme producing a slight improvement in the RMSF value for visibility and the mean is shifted closer to 1 for the T+1 to T+3 forecasts. There is no change in the statistics for the temperature output of the models, which is to be expected since no change to the temperature scheme has been made.

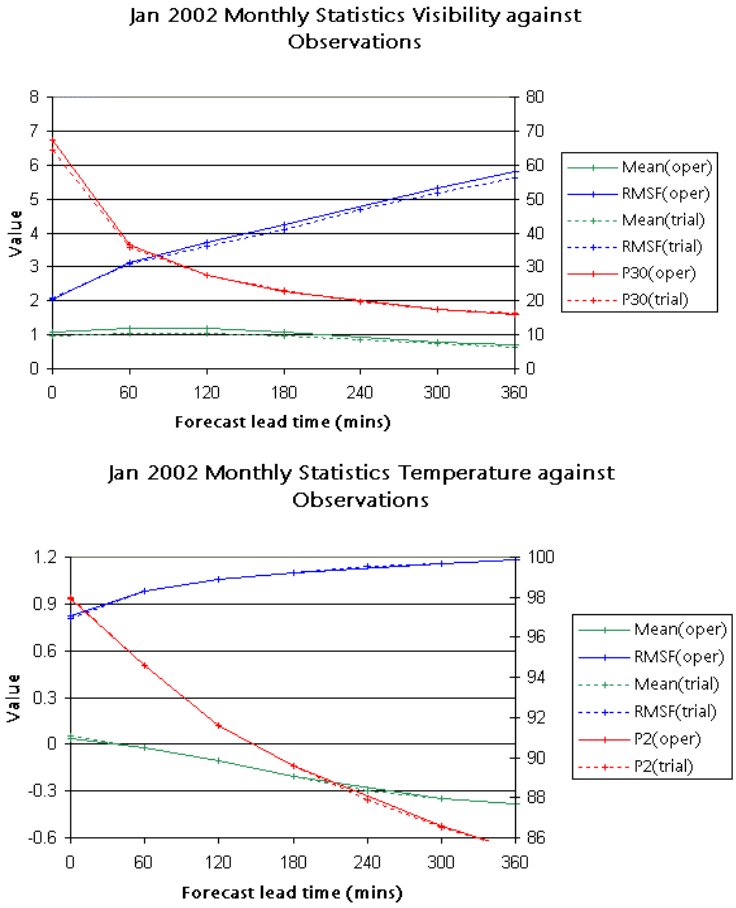

Figure 4.3: Statistics for January 2002 showing a comparison between the old and new schemes for forecasts evaluated against observations. Entire range of visibility considered.

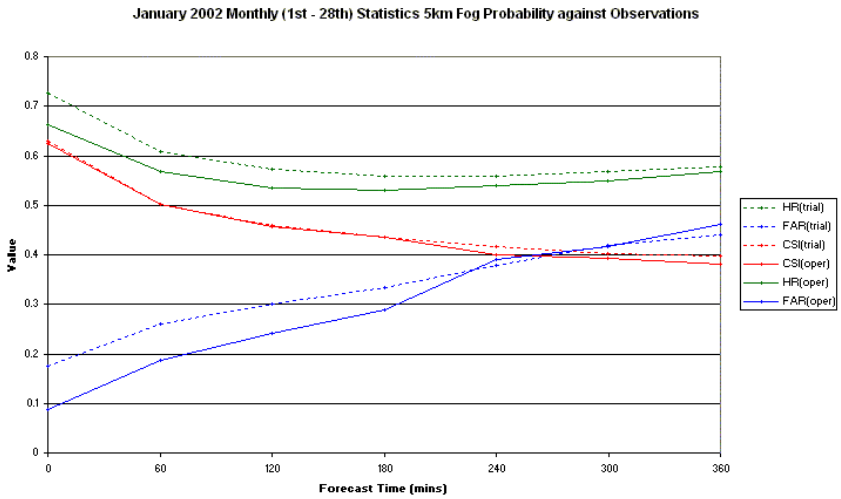

Figure 4.4: Statistics from a comparison between the old and new Scheme for Forecast against observation of visibilities less than 5km

Figure 4.4 shows the changes in Hit Rate, False Alarm Rate and Critical Success Indices between the old and new schemes for visibilities less than 5km. Although the HR has increased, so has the FAR in the shorter range forecasts (T+1 to T+3) leading to no change in the CSI until the forecasts for T+4 and beyond, where the CSI shows an improvement.

There is only a small signal of improvement from the results based on a whole month because the weather was very dry for the first half of the month, diluting the effect of the new scheme. To see how the model is performing in periods of widespread precipitation, the verification statistics for one week (starting 21st January 2002) have been processed and displayed. The weather this week contained both rain and snow bands.

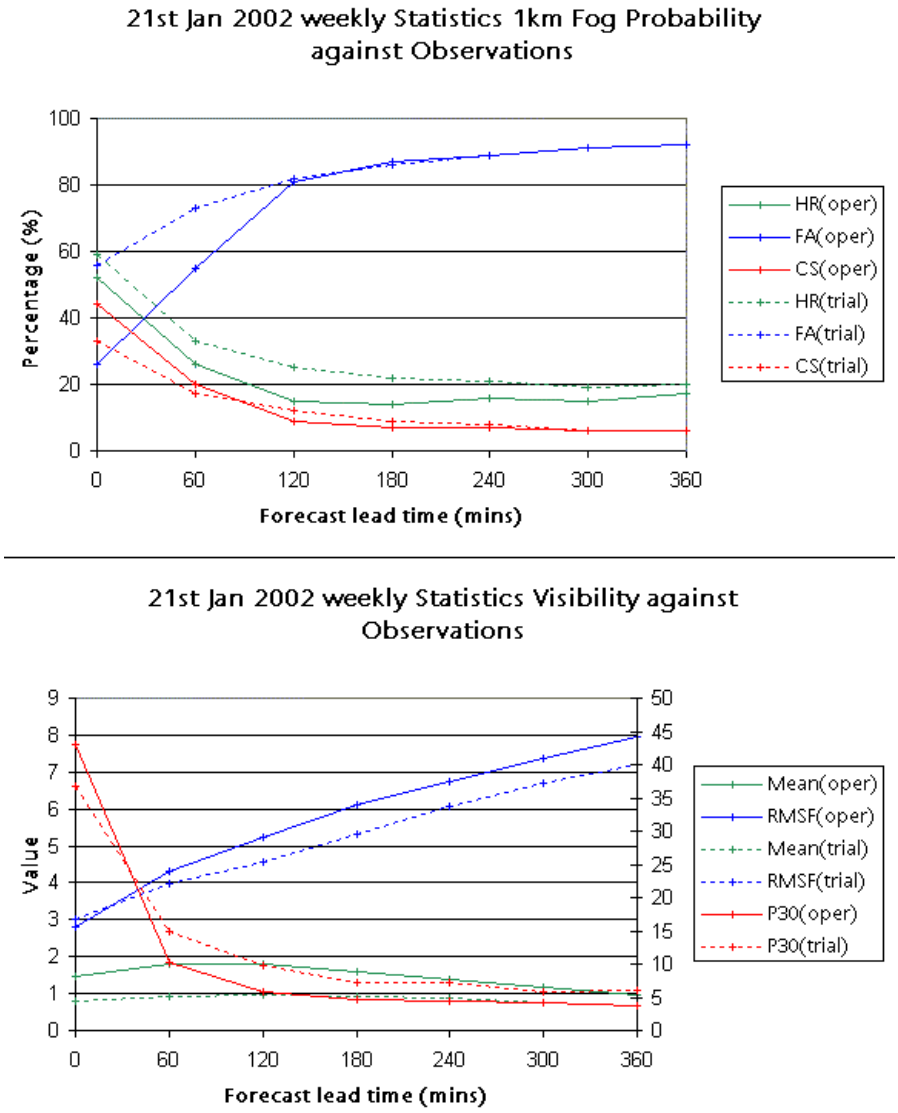

Figure 4.5: Statistics from a foggy 7-day period using evaluation against observations. Upper plot shows statistics for the probability of the visibility being less than 1 km. The lower plot shows statistics from the deterministic fog visibility for the entire range of visibilities.

Figure 4.5 shows the statistics produced when comparing the forecast for each scheme against the observed visibilities for that time. The HR, FAR

and CSI values for the 1km visibility threshold are displayed with the mean, RMSF and P30 statistics for the visibility fields. The HR has improved at all time steps, but an increase in the FAR up to T+1 (after which it is at operational values) has lead to a decrease in the CSI up to T+1 followed by an increase in the CSI values at later time steps. The mean value is much closer to 1 and there is a decrease in the RMSF values from T+1 to the end of the forecast sequence. The P30 values have increased at the same lead times.

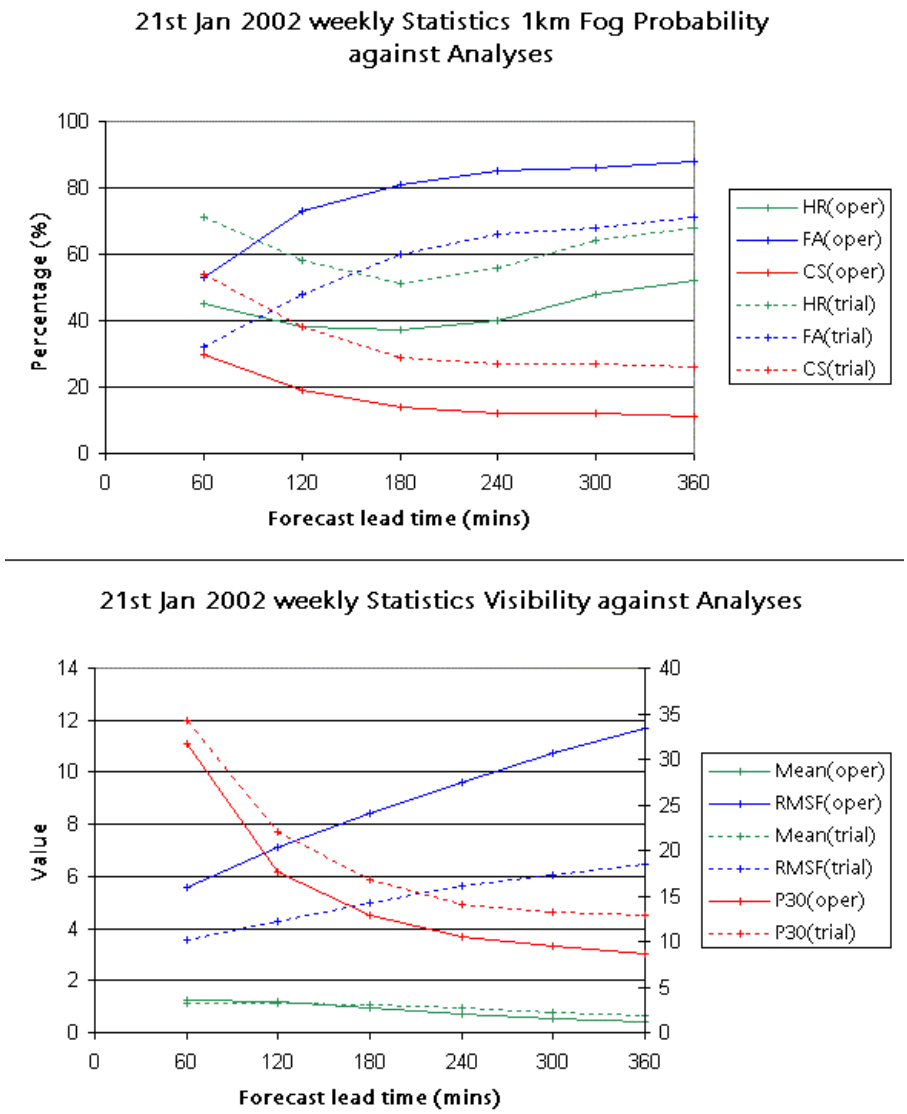

Figure 4.6: Statistics from a foggy 7-day period using evaluation against analyses. Upper plot shows statistics for the probability of the visibility being less than 1 km. The lower plot shows statistics from the deterministic fog visibility for the entire range of visibilities.

Figure 4.6 shows the statistics when the forecasts from each version of the scheme are compared with the subsequent analyses. The changes HR, FAR and CSI are displayed for the 1km threshold and for the mean, RMSF and P30 values for visibility. These graphs show a marked improvement in the HR and the FAR is noticeably lower at all forecast times leading to a definite improvement in the value of the CSI at all points in the forecast sequence.

The RMSF values are noticeably reduced, the P30 values are higher, and the mean values are slightly closer to 1. The increase in the P30 demonstrates that the improvement is occurring mainly in what were the outlying results.

Figure 4.7 shows HR, FAR and CSI values from comparisons of visibilities below the 5km threshold against observes values. The large increase in the HR is accompanied by a similar increase in the FAR at T+0. However, the increase in FAR declines more rapidly with lead time than the increase in HR. The net result is an increase in CSI at all times.

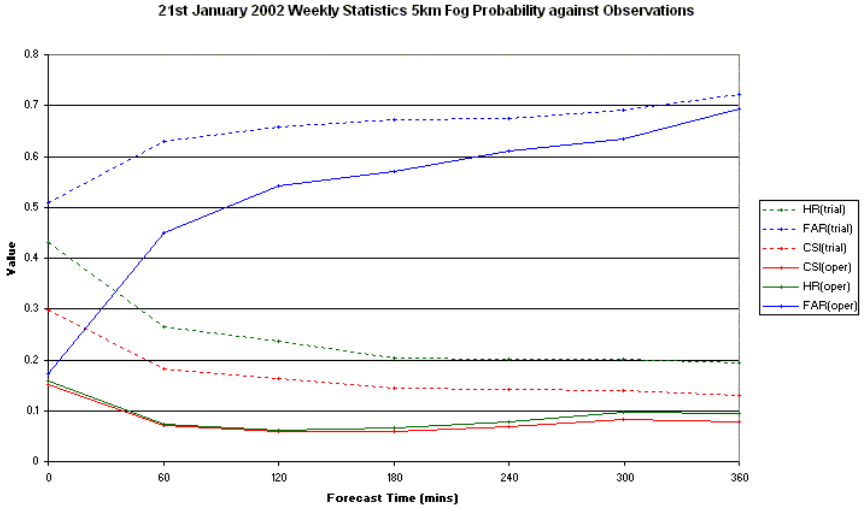

Figure 4.7: Statistics for a 7-day foggy period for the old and new versions of the probabilistic forecast schemes for a 5 km threshold. Evaluation is against observations.

These statistics show more benefit from the new scheme when compared against analyses than against observations. One reason is the persistence of observed visibility locally. If the observed visibility at a station is low due mainly to precipitation, this low visibility will tend to persist until large weights are given to the mesoscale model forecasts towards the end of the Nimrod forecast sequence. Thus the maximum benefit of adding precipitation will be at locations several grid lengths from an observing station and will therefore have the maximum impact on the forecast against analysis statistics.

The benefit of the new scheme tends to increase with lead time, especially when evaluating against observations. This is believed to be a result of the precipitation forecast advecting the precipitation areas into previously dry areas, giving a marked change in visibility values. The increased weight given to the mesoscale model forecasts at later lead times will also be having an impact here.

The results from the Case Studies, which are described next, show how effective the new scheme is in wide-spread precipitation where the operational scheme is very weak.

5 Case Study of 30th October 2000

This Case Study was chosen as a good case of widespread rainfall across the British Isles with snow falling over high ground of Scotland, Yorkshire and Northern England. (See Figures 4.1 & 4.2 for details of rainfall intensity)

5.1 Extract from *Daily Weather Summary* for Monday 30 October 2000.

A low centre was located over North Wales at 05z. The southern half of Britain began with widespread gales and outbreaks of continuous and heavy rain. Most other parts of the country were dry with clear periods but during the early hours heavy rain spread across Wales and into the Midlands with winds increasing to severe gale, and storm force around south facing coasts.

To the north the weather was quite benign, although the rain gradually extended northwards and started turning to snow in some areas of West and north Yorkshire and across the Peak District to Shropshire.

By midday the wet and very windy weather had cleared away into the North Sea with the winds moderating but bringing some blustery showers around western and southern coasts.

5.2 Method

The Case Study data for 06Z was processed three times. This gave output from three different schemes:

- The Operational VAFS program
- The New VAFS program taking account of the precipitation
- The New VAFS program modified to ignore observations in precipitating areas in the analysis.

The output from these models is shown in figures 4.1 & 4.2 along with the rain rate and snow probability fields.

Visually these images look very plausible, there are clearly lower visibilities where rain is falling, with very much lower visibilities in the regions of snow fall over N Wales and NW England. Closer inspection reveals that the new precipitation scheme over compensates for precipitation in the region of ingested observations (due to double accounting, see section 3.4.1). In the version of the scheme which removes these observations, the resulting visibility is closer to that theoretically expected from the rainfall intensity.

One downside to the removal of all observations in precipitating areas can be seen in the analysis image as the hill fog over the Mendip hills in Somerset which the observations is show is spurious. This hill fog comes from the background field, and has been overruled by nearby observations in the analysis which uses observations in areas of precipitation. A more selective scheme for eliminating observations has been considered. Such a scheme would not eliminate any observed visibility which was substantially different from a visibility produced by the model.

The new scheme makes the largest corrections in the regions where there are no observations, this makes it very difficult to analyse the success of the model in all regions.

5.3 Quantitative Results

To quantify the results, the output visibility fields have been interpolated to the locations of the synoptic observations. These values are shown as scatter plots of observed visibility against forecast visibility in Figure 5.3 for the analyses and T+3 forecast. The data were also analysed using linear regression to obtain a line of best fit and a correlation coefficient (Table 3.1).

From these results, we can see the effect of the new model on the visibility field. The visibility schemes including the effect of precipitation cause a reduction in visibility, which mainly occurs where the observed visibility was below 20 km. This is most obvious for the T+3 forecast, presumably because precipitation has moved over areas which were previously dry where the analysis may have had a high visibility.

The impact of the new scheme is sufficient to move the intercept of the regression line 800 m down the y axis for the analysis and 1200 m for the T+3 forecast. The effect of removing observations coincident with precipitation is not particularly apparent. This is reflected in the fact that the two regression lines for the new scheme with and without observations removed are virtually coincident.

The correlation coefficients from the regression analysis are shown in Table 10.10 for the analysis, T+3 and T+6 forecast. Table 10.10 shows no benefit from excluding observations coincident with precipitation.

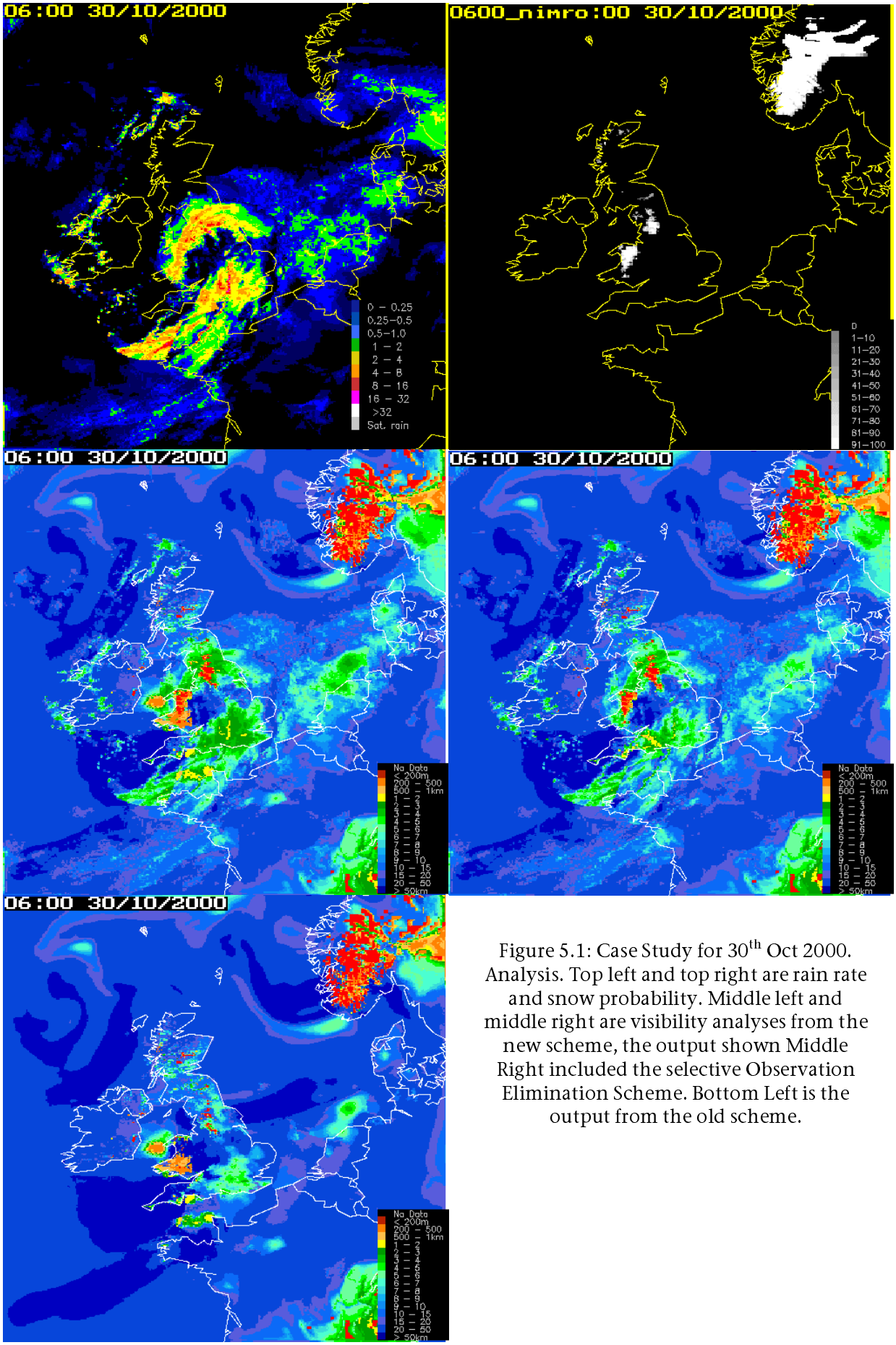

Figure 5.1: Case Study for 30th Oct 2000. Analysis. Top left and top right are rain rate and snow probability. Middle left and middle right are visibility analyses from the new scheme, the output shown Middle Right included the selective Observation Elimination Scheme. Bottom Left is the output from the old scheme.

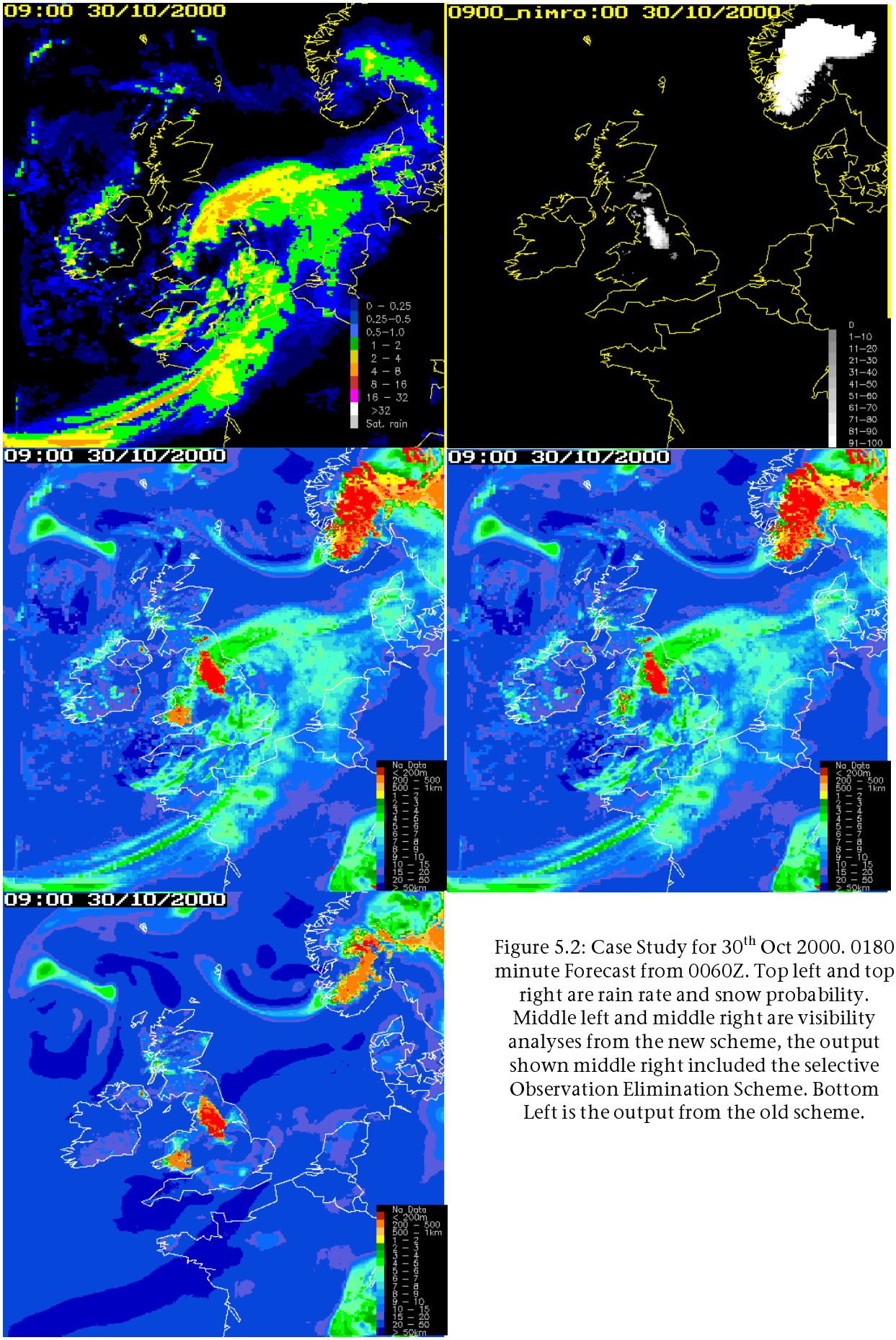

Figure 5.2: Case Study for 30th Oct 2000. 0180 minute Forecast from 0060Z. Top left and top right are rain rate and snow probability. Middle left and middle right are visibility analyses from the new scheme, the output shown middle right included the selective Observation Elimination Scheme. Bottom Left is the output from the old scheme.

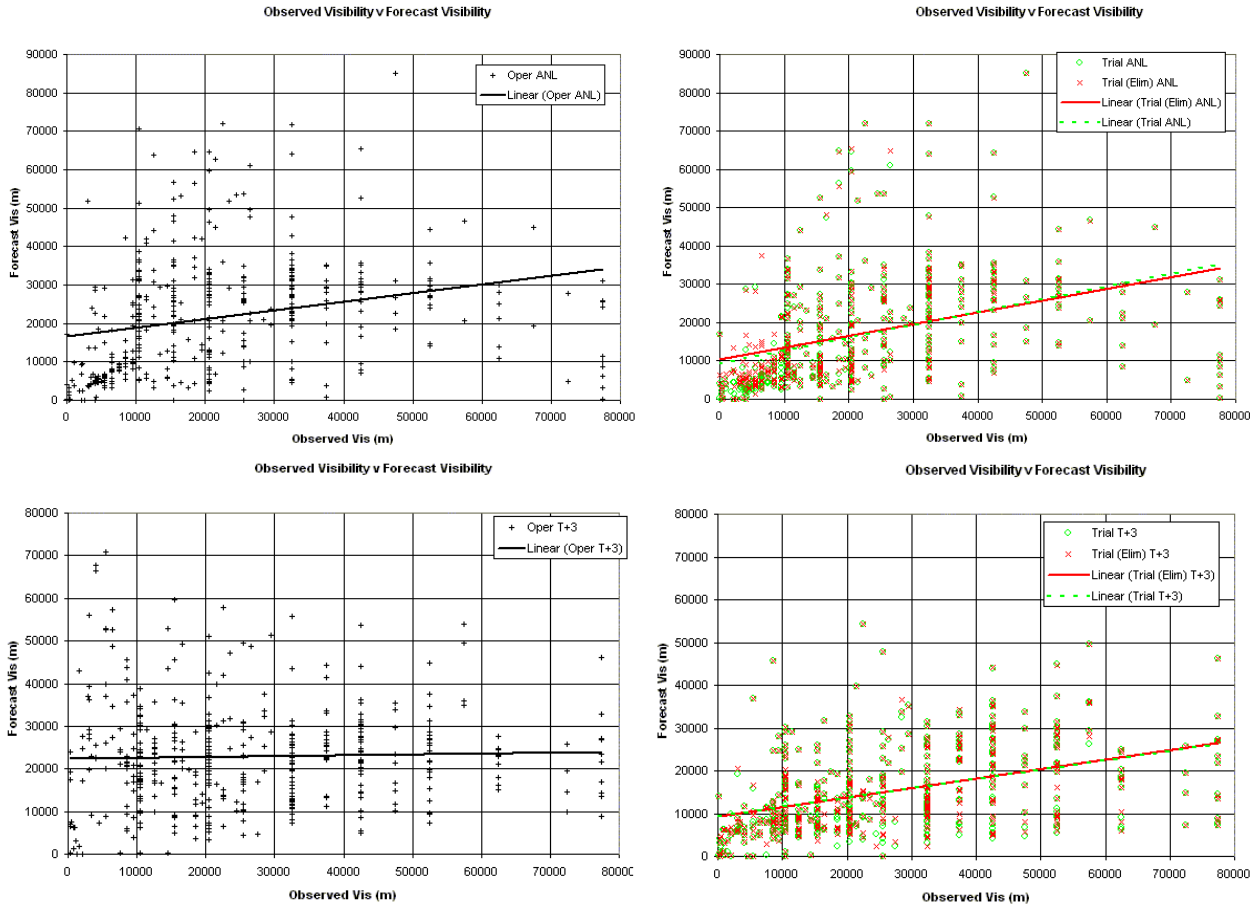

Figure 5.3: Case Study 30th Oct 2000. Scatter plots of Forecast visibility against Observed visibility at Analysis (Top), and 0180 minutes (Bottom). The output from the old operational scheme is shown on the left and an overlay of the two trial schemes is shown on the right, all with regression lines of best fit. Oper = Old Operational Scheme. Trial = New Scheme. Trial (Elim) = New Scheme with selective observation elimination (the observations are not eliminated from the scatter plot).

Table 5.1: Correlation Coefficients for the 9 sets of data are:

Model	Analysis	0180 min Fcst	0360 min Fcst
Old	0.26	0.04	0.05
New	0.41	0.41	0.40
New (elim obs)	0.38	0.41	0.40

6 Case Study of 21st December 1999

6.1 Extract from *Daily Weather Summary* for Monday 30 October 2000

There was rain across Northern Ireland, the West Country, and west Wales. There was also a mixture of rain and sleet across the western fringes of Scotland. Through the night the rain spread east across all but the more eastern fringes of East Anglia and southeast England, but as it did so it turned increasingly to sleet and snow, particularly over higher ground.

During the morning the rain, sleet and snow quickly spread to the remaining eastern parts, while at the same time clearing from the west.

This Case Study was chosen as a good case of widespread snowfall across the British Isles, especially over the Pennines and the hills of southern England. The precipitation was at it's heaviest at 0600GMT, so the trial was run for this time. (See Figures 5.1 & 5.2 for a graphical representation of precipitation intensities and snowfall regions.)

6.2 Method

The Case Study data for 06Z was processed three times, as in Section 5.2.

The output from these models is shown in figures 5.1 & 5.2 at the end of this paper along with the rain rate and snow probability fields.

The result of the new scheme here is to reduce the analysed and predicted visibilities in the regions of snowfall (especially in the Scottish Highlands and Central England) from >50km to <500m and to <200m in the heaviest snowfall. (In Figure 5.2, the low visibilities in extreme west of the British Isles are due to hill fog, not snow).

The very low visibilities from the snow have such a strong influence in Equation (2) that the impact of double accounting (See Section 3.4.1) is negligible. For example, if the visibility due to snow is 300m, then given background visibilities of 20km and 2km, adding in the effect of snow gives visibilities of 296m and 261m respectively.

6.3 Quantitative Results

Figure 6.3 shows the scatter plots produced from this case study. In this case, because the band of snowfall was not wide, and had cleared most of the country by the end of the forecast sequence, the old VAFS scheme does much better than the previous case (See Section 5.3). The improvement in correlation coefficients by the two new schemes is not very large. The improvement achieved by the new scheme can be better seen in the smaller offset of the regression lines (which pass closer to the origin) indicating an improvement in the regions of lower visibility.

There is some indication that the new scheme may be forecasting lower visibilities than observed in the snowfall regions eg the line of very low analysed visibilities where the observed visibility was up to 12 km. This may be due to no snow falling at the time of the observation, or because Nimrod incorrectly forecast snow instead of rain. Closer inspection (See

Figure 6.4) reveals a cluster of such points where the observed visibility is ~3km, but the forecast visibility from the new scheme is ~800m, the value for light snowfall (~1mm hr^{-1} See Figure 3.1). There is another cluster of points where the observed visibility is between 6 and 9km (values for moderate rain, see Figure 3.1), with the new scheme forecasting between 2 and 3km (values for very light snow or heavy rain, see Figure 3.1), this is likely due to the model predicting mixed rain and snow, where the snow has already melted at the point of observation. The Nimrod precipitation-type scheme is known to over forecast snow and mixed conditions and it is being revised to rectify this.

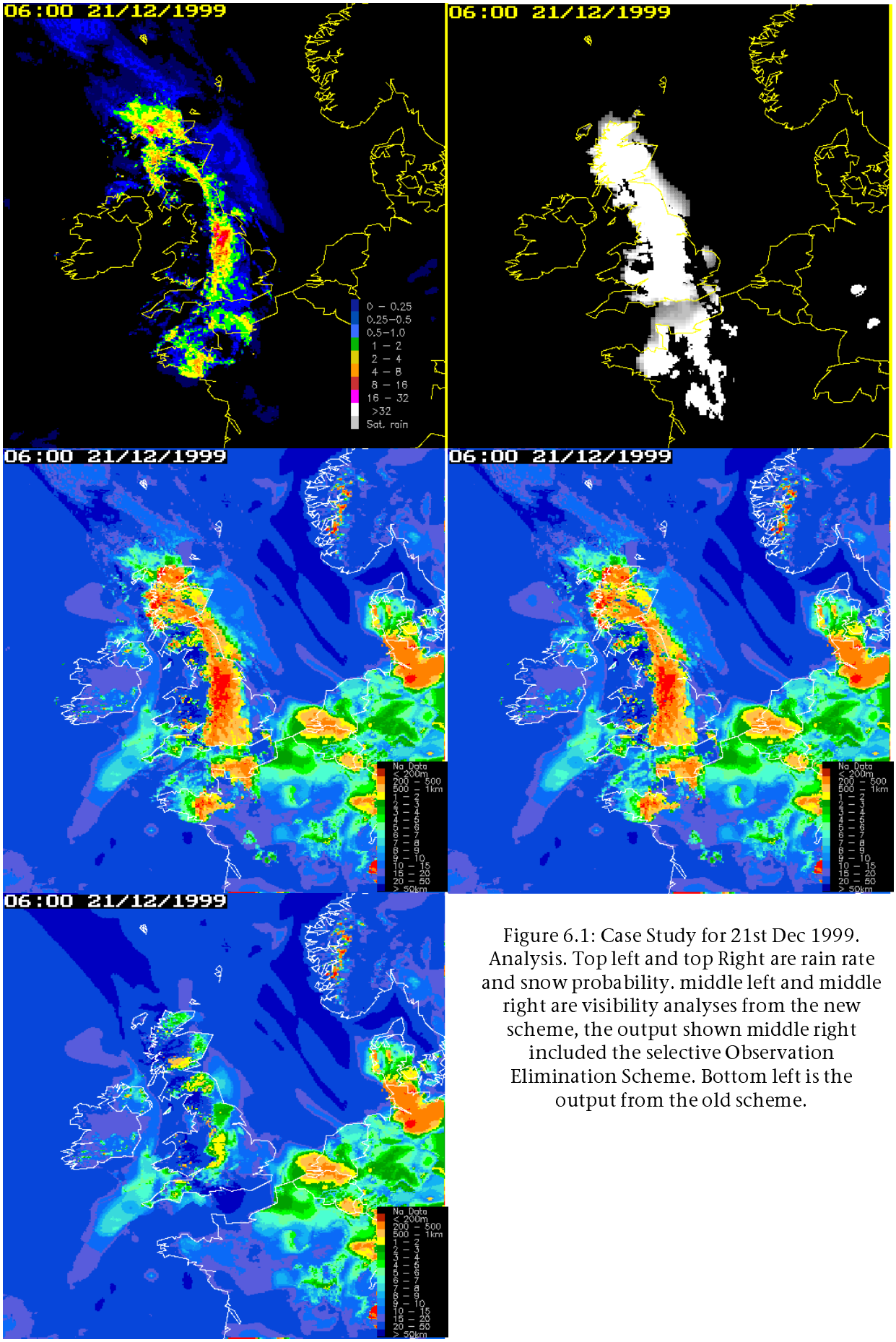

Figure 6.1: Case Study for 21st Dec 1999. Analysis. Top left and top Right are rain rate and snow probability. middle left and middle right are visibility analyses from the new scheme, the output shown middle right included the selective Observation Elimination Scheme. Bottom left is the output from the old scheme.

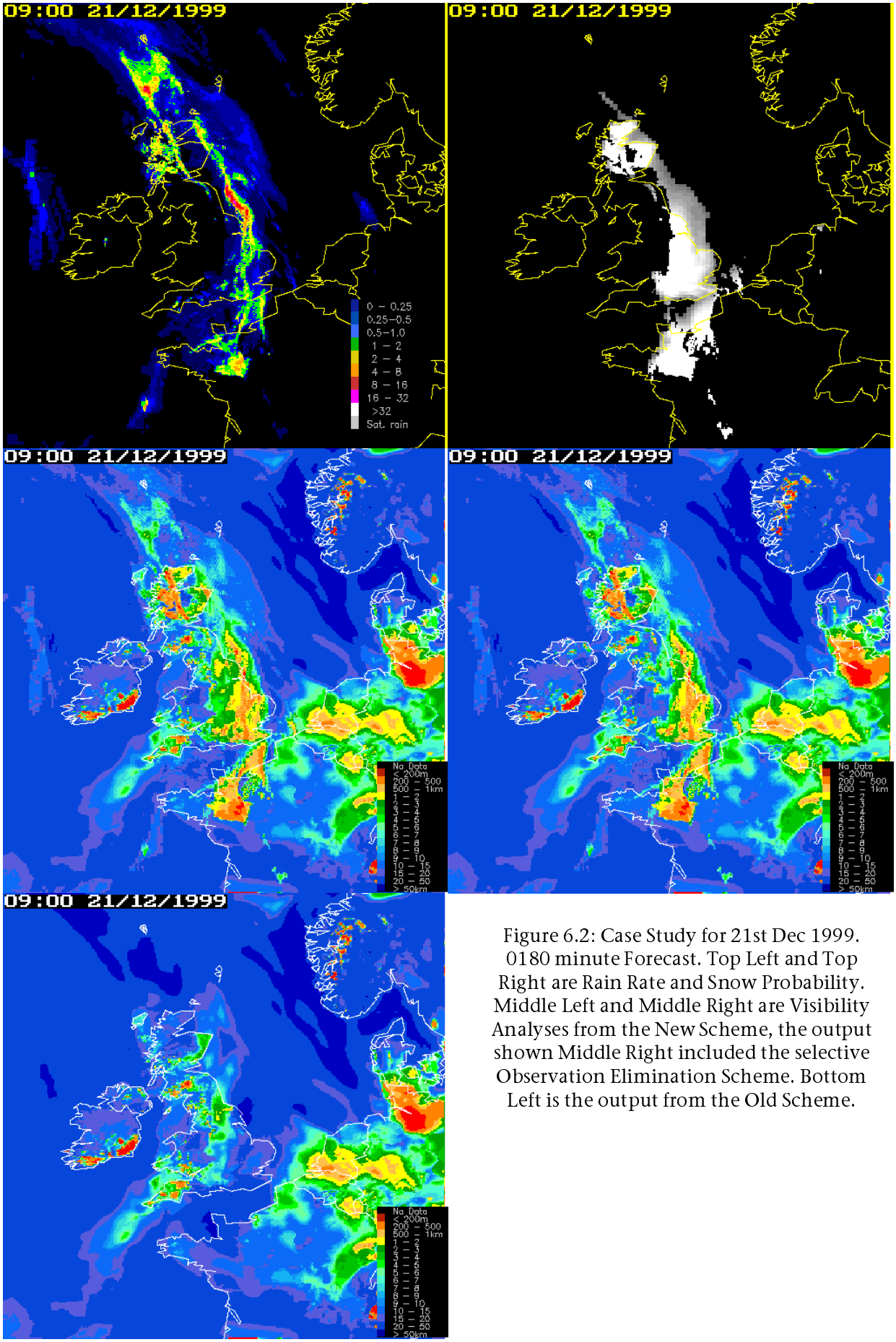

Figure 6.2: Case Study for 21st Dec 1999. 0180 minute Forecast. Top Left and Top Right are Rain Rate and Snow Probability. Middle Left and Middle Right are Visibility Analyses from the New Scheme, the output shown Middle Right included the selective Observation Elimination Scheme. Bottom Left is the output from the Old Scheme.

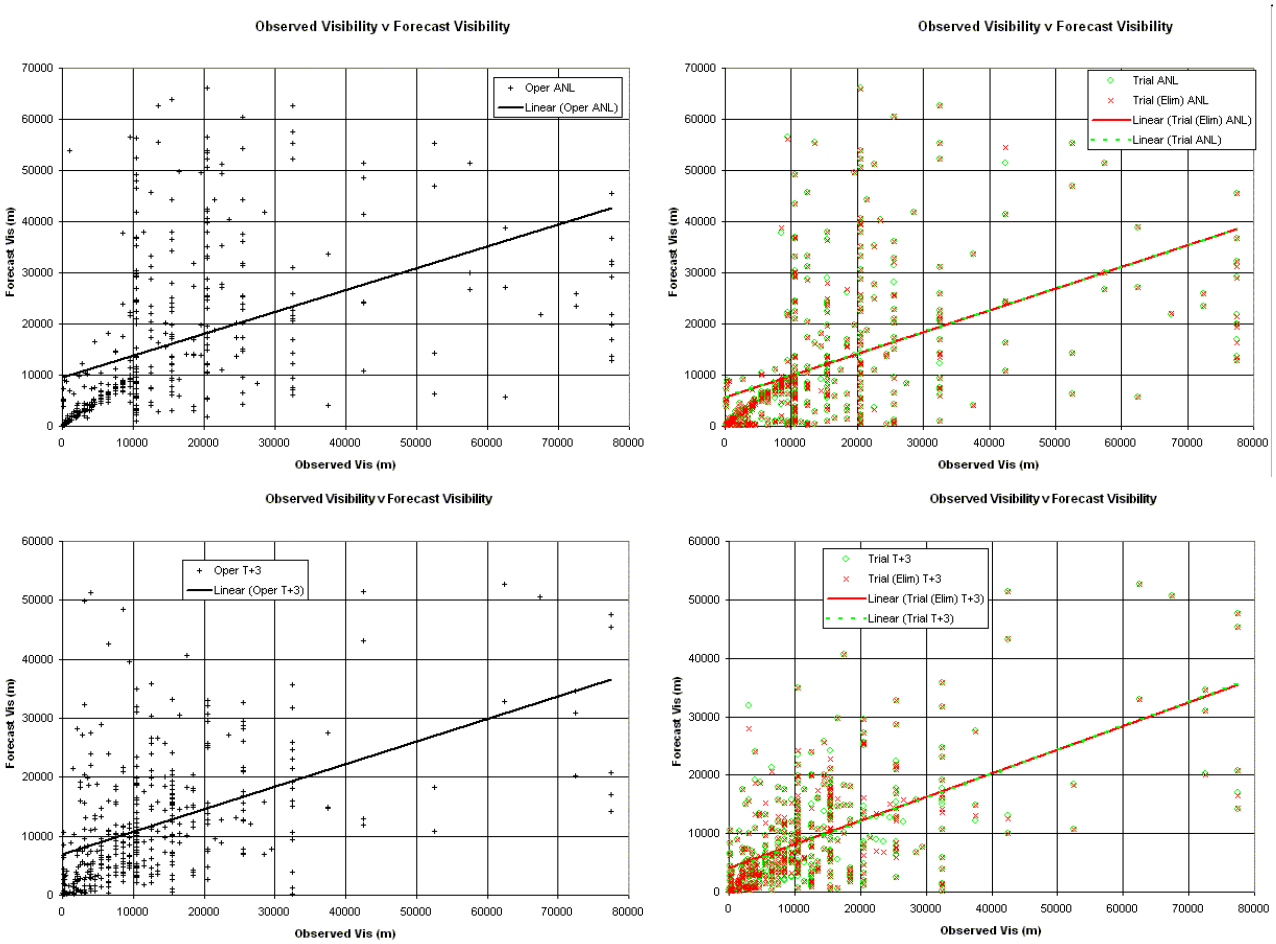

Figure 6.3: Case Study 21st Dec 1999. Scatter plots of forecast visibility against observed visibility at analysis (Top), and 0180 minutes (Bottom. The output from the old operational scheme is shown on the left and an overlay of the two trial schemes is shown on the right, all with regression lines of best fit. Oper = Old Operational Scheme. Trial = New Scheme. Trial (Elim) = New Scheme with selective observation elimination (the observations are not eliminated from the scatter plot).

Table 6.1: Correlation Coefficients for the 9 sets of data are:

Model	Analysis	0180 min Fcst	0360 min Fcst
Old	0.44	0.41	0.39
New	0.47	0.50	0.47
New (elim obs)	0.47	0.49	0.46

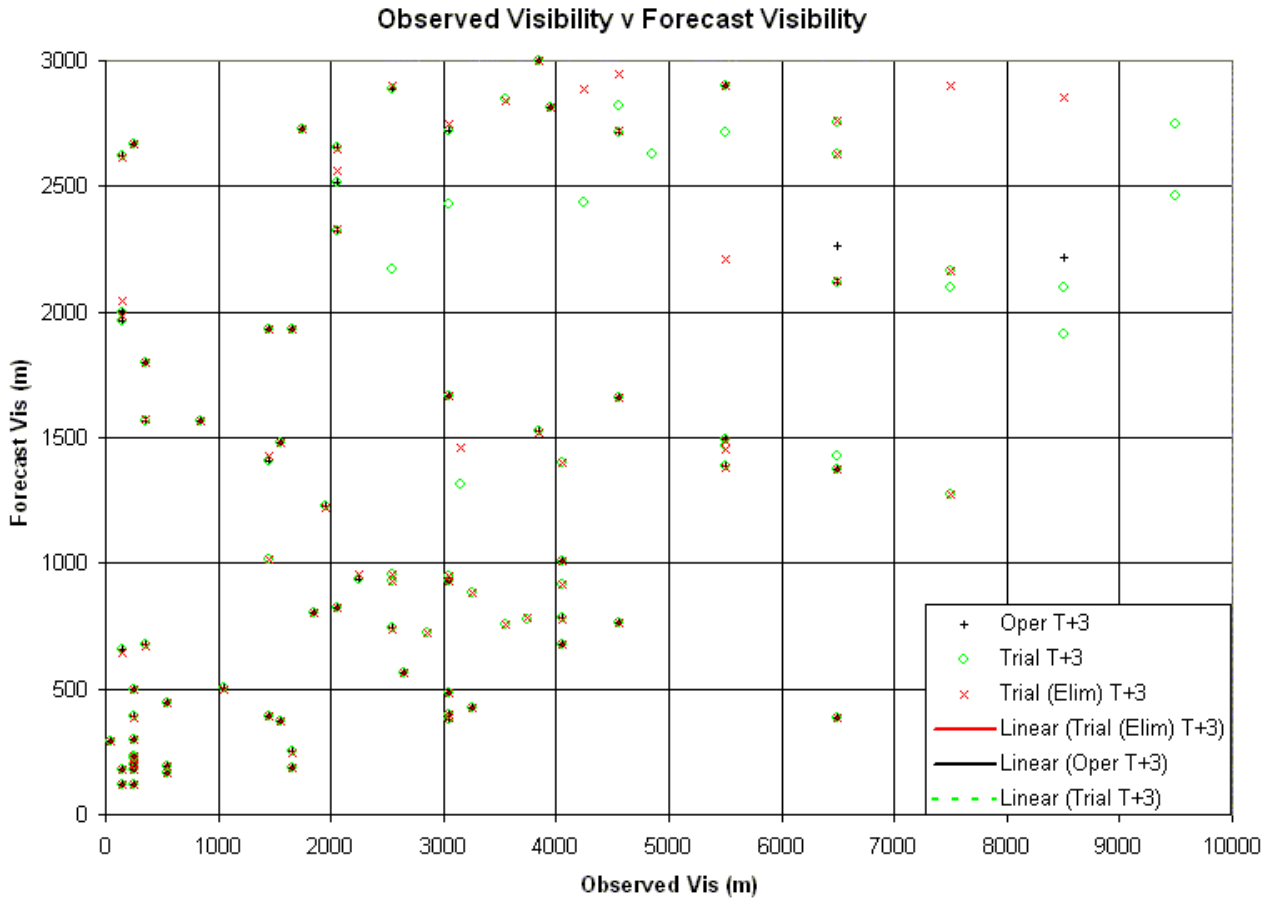

Figure 6.4: Enlarged section of the 0180 minute forecast against observation scatter plot in Figure 6.3 to show where the new scheme is predicting worse visibilities than observed. The operational scheme results are overlaid with the results from the two trials.

7 Conclusion

A new version of the Nimrod visibility analysis and forecast including allowance for the effect of precipitation on visibility has undergone a real-time trial between November 2001 and January 2002. The trial found quantitative improvements due to the scheme and also indicated some limitations.

Case studies were also performed. During these, a revised version of the new scheme was tested which removed observations coincident with precipitation during the analysis, in order to avoid double accounting for the effects of precipitation.

The results from the real-time trial was analysed using existing visibility verification techniques producing Hit Rate, False Alarm Rate and Critical Success Indices to determine improvements at visibility thresholds of 200m 1km and 5km.

Case Studies were analysed by direct comparison between synoptic observations and equivalent points from the forecast field. The forecasts were also evaluated against analyses. Correlation and Regression coefficients were produced to quantify improvements.

The main conclusions are:

- The scheme including precipitation effects was found to be significantly better than the operational scheme both subjectively and objectively. This was especially true when the forecasts were evaluated against analyses. There was a tendency to predict too low a visibility, especially when evaluating against observation, believed due to the ingestion of observations of visibility in rain during the analysis.
- In cases of rainfall, the scheme which ignored observations coincident with precipitation was found to improve slightly on the new scheme, but at the expense of details such as hill fog. A more selective scheme should be considered.
- In cases of snow, the new scheme was found to be better than the old scheme, except where the Nimrod prediction of precipitation phase or rate may have been in error.
- The observation elimination scheme was found to have made little difference in snowfall.

It is recommended that implementation of the new VAFS scheme taking into account precipitation should be implemented, but without the elimination of observations coincident with precipitation. The latter didn't make a sufficient difference to warrant the added complexity.

8 Appendix: Overview of adjustments

Visibility diagnostics program (visdiag.x) altered to read in the Nimrod merged rain rate and snow probability fields for analysis and each forecast time.

Subroutines vis_process.f and fogprob_from_qt_t.f have been altered to make use of the rain rate and snow probability fields.

New subroutine precip_adjust.f90 included in vis_process.f to adjust the main visibility and worst visibility output where precipitation is analysed.

Subroutine get_obs.f adjusted to write a better formatted ASCII text file of observations available and to check for the existence of this file before accessing the Horace database if it does not exist. This enables 'offline' execution of visanl.x.

Subroutine eliminate_precip_obs.f90 written to remove observation data in precipitating regions. This also caused a necessary change to visanl.f, which calls this subroutine, and requires a new argument (the location of precipitation data) to be passed in from the calling shell script.

9 Appendix: Data Requirements for the Revised Scheme

For more information on the use of this data, see *Wright, 1997*

9.1 Mesoscale Model data

The Mesoscale Model (MM) variables required by NVAFS are:

a) Screen liquid water temperature, T_L.

b) Screen total water content, q_t.

c) Surface pressure, p.

d) Level 1 aerosol mass mixing ratio, m.

e) Surface Temperature, T_s.

f) Orographic height, h.

9.2 Cloud Analysis and forecast data

If the hill fog processing is used within the visibility diagnostics code, then the analysis and forecast multi-level cloud fields are required (15km resolution)

9.3 Surface observations

All surface SYNOP and SHIP reports available within the Nimrod domain are used; the elements required are:

a) Visibility, Vis.

b) Screen Temperature, T.

c) Screen dew point, T_d.

d) Mean sea level pressure, p_{MSL}.

e) Total cloud cover.

f) Wind speed.

In addition, a number of station attributes are also required:

a) Latitude, Lat.

b) Longitude, Lon.

c) Station height, h.

d) Station number/Ship call-sign.

9.4 Included in the new scheme

a) Nimrod rain rate (using merged radar and MM rain rate), RR.

b) Nimrod snow probability, P_{snow}.

10 References

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